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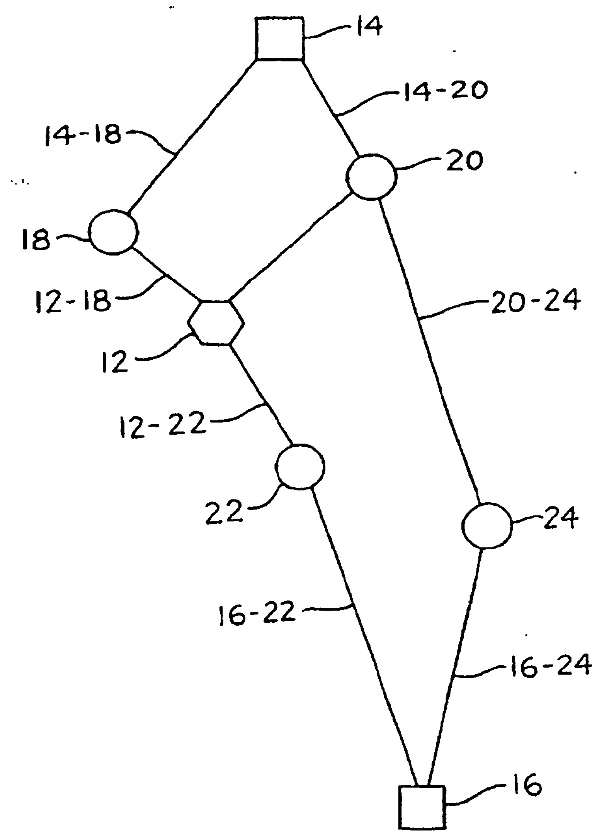
(54) Title: TRANSCEIVER WITH CALL SWITCHING CAPABILITIES IN ARBITRARY NETWORKS

(57) Abstract

A relay communications network is configured from a plurality of transceiver stations (12, 14, 16, 18, 20, 22 and 24) in a given area to transmit a message at a minimum transmission power by causing the station (12) which is to originate the transmission to interrogate those stations (18, 20 and 22) with which it can communicate directly as to their ability to communicate either directly or indirectly with a target station (14 and 16), causing each relay station (18, 20, 22, and 24) which can communicate with the target station to transmit to the originating station information as to a path by which relay station can communicate with the target station with a minimum transmission power and causing the originating station to select a serial call path through one or more of the relay stations.



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TRANSCEIVER WITH CALL SWITCHING CAPABILITIES IN ARBITRARY NETWORKS

FIELD OF THE INVENTION

The present invention relates to communication networks in general and is particularly directed to a method of establishing an arbitrary network to provide a serial call path which requires the minimum expenditure of transmission power to transmit a message from an originating station to a target station through one or more relay stations without the use of a central control switch.

SUMMARY OF THE INVENTION

According to the present invention, a communications network of a plurality of stations, including one or more relay stations, establishes an arbitrary network serial call path between an originating station and a target station which cannot communicate directly with one another at a selected transmission power level by causing each of one or more of the relay stations which can communicate directly with the originating station to transmit to the originating station information as to those other stations in the network with which the relay station can communicate, causing the originating station to select an arbitrary network of said relay stations to provide a serial call path in order to transmit the message to the target station at a minimum expenditure of transmission power, and then transmitting the message over the arbitrary network. In said network, stations may be selectively disabled from functioning as a relay station, so as to be operable only as an originating station or as a target station for the period of time that said station is selectively disabled from functioning as a relay station.

BRIEF DESCRIPTION OF THE DRAWING

The invention may be more readily understood by reference to the accompanying drawing, in which:

Fig. 1 is a block diagram of a communications network according to the present invention; and

Fig. 2 is a block diagram of a wireless transceiver adapted for use in the communications network of Fig. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to Fig. 1, there is shown a block diagram of a communication network 10, comprised of stations 12, 14, 16, 18, 20, 22 and 24. In the preferred embodiment, all of these stations 12-24 are transceivers, capable of transmitting and receiving communications in the 2,000 megahertz range. The present invention is particularly adapted for use in wireless transmissions in that frequency range. While each of the stations 12-22 may be an identical transceiver capable of independently originating and receiving a message, in the practice of the present invention, for purposes of illustration, station 12 will be considered to be a station which originates a message, and stations 14 and 16 will be considered to be designated target stations, which are to receive different individual messages transmitted from the originating station 12. Stations 18, 20, 22 and 24 will be considered to be relay stations for purpose of this explanation. Each of the stations 12-24 is assigned a unique identification code which may be used to address that station from one of the other network stations, and is used to identify that station in responding to a transmission from one of the other network stations. For purposes of this example, the following Table I will set up the path designations and power losses for transmissions between adjacent stations.

TABLE I - PATH POWER LOSSES

Path	Power Loss in dB
12-18	12
12-20	20
12-22	14
14-10	25
14-20	16
16-22	32
16-24	20
18-20	22
10-24	30
22-24	15

It is assumed that, unless a path is shown in Fig. 1, two stations cannot communicate directly with one another. In Fig. 1, station 12 is represented by a hexagon and designates a message originating station. Stations 14 and 16 are represented by squares, and indicate stations which will be designated as target stations in the explanation. Stations 18, 20, 22 and 24 are represented by circles, indicating that, for purposes of the examples given with respect to Fig. 1, unless otherwise stated, these stations operate as relay stations, rather than as originating stations or target stations. In the preferred embodiment of the invention illustrated in Fig. 1, each of the stations 12-24 may function as a transceiver and each is selectively operable to not function as a relay station, absent which selection, the station functions as a relay station.

In the present invention, each of the relay stations 18-24 periodically transmits an audit request signal at a standard power output to all of the other stations with which it can directly communicate, requesting the other stations to send to the requesting relay station the other stations' identification codes and signal strengths (power loss) of the audit request signal as received by the other station. Each station receiving this request transmits this information to

the requesting relay station, and, when received by the requesting relay station, is placed in an inventory maintained by the requesting relay station for use in the event the requesting relay station is called upon to function as a relay station in setting up a serial call path between an originating station and a target station.

By way of a first example, assume that it is desired to transmit a message from originating station 12 to target station 14. Originating station 12 will utilize the identification code of station 14 to designate station 14 as the target for the message to be sent from station 12 and will attempt to communicate directly with the target station 14. This communication may be by any conventional means, such as by microwave transmission, fiber optic transmission, or the like. In the presently preferred embodiment, the transmission would be by electromagnetic radiation in the 2,000 megahertz band. Thus, the originating station transmits a direct call path inquiry utilizing the identification code of the target station which, if received by the target station, causes the target station to respond directly to the originating station, in which event the originating station transmits the message directly to the target station. However, as is shown in Fig. 1, the originating station 12 cannot communicate directly with the target station 14. If the target station had been designated as any of stations 18, 20 or 22, rather than station 14, the message could have been transmitted directly to such station by originating station 12.

When the originating station 12 determines that it cannot communicate directly with the target station 14, the originating station 12 directs an inventory request to each relay station 18, 20, 22 with whom it can communicate directly, inquiring as to whether that station can communicate directly with target station 14 and, if so, the power loss of the call path between the relay station and target station 14.

Thus, referring to Fig. 1, the relay station 18 would transmit to the originating station 12 the information

that the relay station 18 had received an audit signal request from the originating station 12 with a path power loss for the path 12-18 of 12 dBm, and can communicate with station 14 by path 18-14 with a path power loss of 25 dB. Similarly, the relay station 20 will respond to the inquiry by transmitting to the originating station 12 the station 20 inventory indicating that it can communicate with station 14 over the path 14-20 with a path power loss of 16 dB, and with originating station 12 over the path 12-20 with a path power loss of 20 dB.

One of the principal objects of the present invention is to transmit the message between the originating station 12 and the target station 14, utilizing the minimum overall transmission power required to provide a preselected signal to noise level of the message signal ultimately received at the target station. The originating station 12 processes the inventory information received from the relay stations 18 and 20 and determines that each can provide a call path between the originating station 12 and the target station 14, that is, call paths 12-18, 18-14, and call paths 12-20, 20-14. Referring to Table I, the call path loss for the call paths 12-18, 18-14 is (12) + (25) = 37 dB. The call path loss for the call paths 12-20, 20-14 is (20) + (16) = 36 dB. Therefore, since the call path 12-20, 20-14 results in a lower power loss, the originating station 12 will set up call path 12-20, 20-14 to transmit the message to the relay station 20 for relay to the target station 14.

As a second example of the network shown in Fig. 1, assume that the originating station 12 wishes to transmit a message to the target station 16. Again, the originating station cannot communicate directly with the target station. The initial transmission of a signal directed specifically to target station 16 does not produce any response from target station 16, so that the originating station 12 does not then attempt to transmit the message directly to target station 16, but again transmits an inventory request to relay stations 18,

20, 22 and 24, inquiring if they can communicate directly with target station 16. Only relay station 22 responds, indicating that it can communicate directly with the target station 16. The originating station 12 then establishes the call path 12-22, 22-16 to the target station 16 and the message is transmitted by the originating station 12 to relay station 22 for relay to the target station 16, and relay station 22, upon receiving the message, relays it to target station 16.

As was stated above, in the preferred embodiment, the operation of a station in the relay mode is a selective option, that is, any station can be selectively disabled as to functioning as a relay station and so will not respond to an inventory request. For the purposes of the next example, assume that relay station 22 has been so selectively disabled, so that the call path 12-22, 22-16 between the originating station 12 and the target station 16 now no longer exists. Consequently, the inventory request from the originating station 12 will not result in any relay station transmitting an inventory to the originating station 12 indicating that the relay station can communicate directly with target station 16. Upon such an occurrence, in the currently preferred embodiment, the originating station 12 transmits a second inventory request signal to all of the relay stations, requesting the relay stations to interrogate those relay stations with which the relay station receiving the second request can communicate, to inquire if any of these other relay stations can communicate directly with the target station. In the example in Fig. 1, this second relay request, when transmitted by the originating station 12, will be received by the relay stations 18 and 20. Relay station 20 will transmit the request to relay station 24 and receive back from relay station 24 information that relay station 24 can communicate directly with the target station 16, together with the path power loss information. Relay station 20 will then transmit this information to the originating station 12, together with the path power loss for the serial call path 12-

20, 20-24, 24-16 of (20), (30), (20) = 70 dB.

In the above example, only relay station 20 could communicate directly with another relay station which, in turn, could communicate directly with target station 16. If any other relay station had also transmitted to the originating station 12 the information that the other relay station could, through a third relay station, communicate directly with the target station 16, the originating station would determine which call path had the minimum power loss and select that call path for transmission of the message. As an example of such a situation, assume that the call path 16-22 does not exist. Again, the originating station 12 is not able to communicate directly with the target station 16, and cannot communicate with target station 16 through any single relay station. As shown in Fig. 1, the two possible serial call paths are 12-22, 22-24, 24-16 (49 dB loss) and 12-20, 20-24, 24-16 (70 dB loss). Upon initiating a second inventory request, the originating station 12 will receive call path power loss inventory information for target station 16 from both of the relay stations 20 and 22, select and establish serial call path 12-22, 22-24, 24-16 as the call path to be utilized for minimum expenditure of transmission power, and transmit the message to relay station 22 for relay to relay station 24 for final relay to target station 16.

The preceding examples refer only to the transmission of a single message between the originating station and the target station. However, most utilization of the present invention will embody the ability to initiate two-way communication between the originating station and the target station, that is, the exchange of messages or data originated at both stations after the original call path is established. In order to provide for such two-way transmissions, the serial call path, once established, is maintained for a selectable time period, in order to permit the rapid exchange of messages, such as by speech or computers. When the two-way transmissions are completed, the

call path is disestablished.

While it is possible to implement such a system using only a single communication channel, such a system will have numerous disadvantages. For example, if a relay station can transmit or receive only one message at a time, its operation as an originating station is precluded for such time as it functions as a relay station, and vice versa. Consequently, in the preferred embodiments of the present invention, a multiplexing system is utilized to provide a plurality of simultaneous transmissions and/or receptions and/or relays so as to increase the network efficiency. A given station may then, for example, function simultaneously as an origination station for its own messages and as a relay station for one or more other call paths. While a frequency multiplexing system could be used, the presently preferred embodiments utilize a time division multiple access (TDMA) system. Such a system is particularly advantageous in an embodiment of the present invention in which each station in the network for a given area is a wireless digital transceiver operating in the 2,000 megahertz range.

By way of example, in a TDMA system, a given standard segment of transmission time is divided into a series of time increments, or slots. Assume, for example, that a five slot system is utilized. One slot in such a system is dedicated for use in controlling the transceiver and the network, and transmits and receives various control information, including station identification codes, path loss information, time slot availability, and the like. Since, in such a system, the actual time available for a given slot is only about one-fifth of the real time involved in, for example, a voice message, the information, if in analog form, is converted to digital form and then compressed at the originating station to fit into the time duration for a time slot. If the information is already in digital form, it is simply compressed to fit in the time slot. The compressed digital information is then transmitted over the call path in

a selected time slot to the target station, where it is decompressed and, if appropriate, converted back into analog form. Since in the assumed five slot system there are four slots open for transmission of messages, the transceiver can simultaneously act as an originating station or a target station for one call path while acting as a relay station for up to three other call paths, or simply act as a relay station for four call paths simultaneously.

Referring now to Fig. 2, which is a block diagram of a transceiver 30 suitable for use in the present invention as an originating, target or relay station, the transceiver 30 has an antenna 32 for receiving an electromagnetic radiation signal from another station for processing in the transceiver. Transceiver 30 is adapted to transmit and receive digitally encoded information. The transceiver 30 has a high pass filter 34 and a low pass filter 36 to which the antenna 32 is connected. The high pass filter 34, and the presently preferred embodiment, passes frequencies at or above the receive frequency, and the low pass filter 36 passes frequencies at or below the transmit frequency. Thus, the high pass filter together with the low pass filter serve to protect the receiver from spurious out-of-band frequencies, and transmitter energy contained in the output signal of the transmitter portion of the transceiver which would otherwise damage the receiver and degrade the performance of the receiver section if applied thereto.

The output of the high pass filter 34 is applied to a low noise amplifier 38. The output of the low noise amplifier 38 is applied to a band pass filter 40. The band pass filter 40 functions to pass only the frequency range of the transmissions to be received by the transceiver. For example, assume that basic transmission frequencies centered on 2,000 megahertz are being used, with receiver and transmitter bandwidths of 10 megahertz each, the bands being separated by 10 megahertz. Within each band are several frequencies or channels (in this example, 10). The low pass

filter 36 filters out frequencies above 1995 megahertz and the high pass filter 34 to passes frequencies which are greater than 2,005 megahertz. In this embodiment, the digital information to be processed by the receive portion of the transceiver is contained in the frequency band which extends from 5 to 15 megahertz below the basic transmitter frequency. The RF energy in this ten megahertz band is applied to a mixer 42. The RF energy in the band is mixed by mixer 42 with the output of the receiver phase-locked loop frequency synthesizer 44 the operation of which is described as follows.

The receiver has a phase-locked loop frequency synthesizer consisting of a phase-locked loop chip (PLL Rx) 46, a voltage controlled oscillator (VCO) 48 and loop filter 50. The output of the loop filter is applied as the voltage input to the VCO 48, the output of which is the output of the receive phase-locked loop frequency synthesizer 44. The PLL Rx chip 46 is provided with an output from a reference crystal oscillator 52 to cause precise and stable output of the various frequencies to be synthesized. The frequencies to be synthesized are selected by a microcontroller, 54, and are set equal to the sum of the intermediate frequency (IF) and the receive frequency. The selected frequencies are applied by the microcontroller 54 to the PLL chip 46.

The transmitter has a phase-locked loop frequency synthesizer 56 consisting of a phase-locked loop chip (PLL Tx) 58, a transmitter voltage controlled oscillator (VCO) 60 and loop filter 62. The output of the loop filter 62 is applied as the voltage input to the transmitter VCO, the output of which is the output of the phase-locked loop frequency synthesizer 56. The PLL chip 58 is provided with an output from the reference crystal oscillator 52 to cause precise and stable output of the various frequencies to be synthesized. The transmit frequencies are synthesized by combining the output of the receiver VCO 48 with the output of the transmitter VCO 60 in a mixer 64 to obtain the difference frequency. From our example, the difference frequency is

equal to 20 MHz plus receiver IF and is input to the transmit PLL chip 58 to select the specific frequency within the transmit band that corresponds to the selected receive frequency.

Demodulation

The IF output of the receiver VCO 48 is fed both to a limiting amplifier (limiter) 66 and to a received strength signal indicator (RSSI) circuit 68. The limiter 84 strips the noise spikes from the waveform and feeds the modulated IF to a discriminator 70, which removes the IF and extracts the digital modulation ("baseband") content. The RSSI circuit 68 produces an output voltage proportional to the logarithm of the input signal over a range of 70 dB.

Baseband Receive Processing

The data stream from the discriminator 70 is fed through a low pass filter 72 which removes the extraneous sideband, to comparator 74, where it is compared with the amplitude of a reference analog level obtained from the microcontroller 54 via an Input/Output Buffer 118 and converted to analog form by the digital-to-analog converter 78. The comparator 74 uses the reference level to distinguish between zeroes and ones. Timing recovery is accomplished by the symbol timing recovery circuit 88, which detects the clock edge in the incoming data in order to synchronize this data with microcontroller 54 timing. The output of the RSSI circuit 68 is converted to digital in the analog-to-digital converter 82 and the peak value of the digitized waveform is obtained and stored in the peak hold detect circuit 84 for monitoring of communication channel quality.

The microcontroller 54 is a microcomputer with a sub-microsecond clock time which is programmed to command and control all operations of the transceiver. Data is transferred between the microcontroller 54 and external digital devices (computers, facsimile machines, etc.) by the

usual serial and parallel ports (not shown). Speech and other forms of audio are transferred into the microcontroller 54 from a microphone 86 through a Codec 88, which compresses and converts the audio to data pulses. The microcontroller 54 sends data pulses through the Codec 88 which decompresses and converts them to audio to drive the speaker 90.

Data output by the microcontroller 54 for transmission is routed through a Gaussian ROM filter 92 which transforms the data into GMSK (Gaussian Minimum Shift Key) form. GMSK is a form of frequency and shift keying modulation which minimizes bandwidth by conditioning the pulse shapes of the transmitted area.

The output of the Gaussian ROM filter 92 is converted to analog by digital-to-analog converter 94 to become the modulating baseband drive signal. This signal is fed to a transmitter VCO 96 where it directly modulates the RF signal output of the VCO 96. The modulated RF signal is then fed to a power amplifier 98. The amplified signal is then fed through the low pass filter 36 to the antenna 32 where it is radiated into space.

In the preferred embodiment, the transceiver 30 may operate as either an originating station, a target station, or a relay station. In certain utilizations of a given transceiver 30, as in a personal communications network, the user, for whatever reason, may not wish to have the transceiver operate as a relay station. The transceiver 30 has a disable control 100 connected to the microcontroller 54 which is selectively operable by the user to disable the relay function of the transceiver 30 for whatever period of time the user may desire. There are many different methods by which the disable control may function, as will be apparent to those skilled in the art. Consequently, while no specific method for such operation is specifically described herein, one such method is to inhibit the transmittal of a response to an inventory request, so that the originating station would have no call path information upon which to include the disabled

transceiver in the arbitrary network for the serial call path from the originating station to the target station.

While the embodiment shown in Fig. 2 is specifically illustrated as a wireless transceiver, obviously the antenna 32 can be replaced with a connector circuit by which the transceiver 30 is utilized in a fiber optic or other line type network. Similarly, any of the stations 12-24 in the network illustrated in Fig. 1 can also be "patched" into a telephone or other conventional type communications system to further augment the range of the network 10.

Although an exemplary embodiment of the invention has been shown and described, many changes, modifications, and substitutions may be made by one having ordinary skill in the art without departing from the scope of the present invention, as set out in the claims hereof.

CLAIMS

The invention claimed is:

1. For use in a communication network having a plurality of relay stations, a method of conveying a message from a message-originating station in said network to a designated target station in said network while utilizing minimum transmitter power output to transmit the message comprising the steps of:

(a) assigning a unique identification code to each of said plurality of stations;

(b) periodically causing each of said relay stations to transmit an audit request signal to all other of said stations;

(c) causing each of said other stations receiving said audit request signal to transmit an audit request response signal to said relay station transmitting said audit request signal, which response signal includes the identification code of said responding station and the signal strength of the audit request signal as received by said responding station;

(d) causing each relay station sending an audit request signal to prepare an inventory of the responses received thereto by identification code and signal strength and to store said inventory;

(e) causing the originating station to designate the target station, determine if the originating station can communicate directly with the target station, and, if the originating station can communicate directly with the target station, establish a call path directly therebetween and transmit the message thereover;

(f) causing the originating station, if it cannot communicate directly with the target station, to transmit an inventory request to each of said other stations which is a relay station, requesting said relay stations to

transmit to said originating station their identification codes and their signal strength inventories, if any, for a direct call path between such relay station and the target station;

(g) causing each station receiving said inventory request to transmit to said originating station its identification code and its signal strength inventory, if any, for a direct call path between it and the target station; and

(h) causing the originating station, if at least one of said relay station inventories contains a signal strength inventory for a call path to the target station, to select a single relay station to provide a call path from the originating station to the target station from the inventory information received, which call path requires a minimum overall expenditure of transmitter power between the originating station and the target station for the receipt of the message at the target station at a signal to noise level above a preselected minimum, establish said call path between the originating station and the target station through said selected single relay station, and transmit said message over said call path at said minimum overall transmitter power expenditure.

2. For use in a communication network having a plurality of relay stations, a method of conveying a message from a message-originating station in said network to a designated target station in said network while utilizing minimum transmitter power output to transmit the message comprising the steps of:

(a) assigning a unique identification code to each of said plurality of stations;

(b) periodically causing each of said relay stations to transmit an audit request signal to all other of said stations;

(c) causing each of said other stations

receiving said audit request signal to transmit an audit request response signal to said relay station transmitting said audit request signal, which response signal includes the identification code of said responding station and the signal strength of the audit request signal as received by said responding station;

(d) causing each relay station sending an audit request signal to prepare an inventory of the responses received thereto by identification code and signal strength and to store said inventory;

(e) causing the originating station to designate the target station, determine if the originating station can communicate directly with the target station, and, if the originating station can communicate directly with the target station, establish a call path directly therebetween and transmit the message thereover;

(f) causing the originating station, if it cannot communicate directly with the target station, to transmit an inventory request to each of said other stations which is a relay station, requesting said relay stations to transmit to said originating station their identification codes and their signal strength inventories, if any, for a direct call path between such relay station and the target station;

(g) causing each station receiving said inventory request to transmit to said originating station its identification code and its signal strength inventory, if any, as to the target station;

(h) causing the originating station, if at least one of said relay station inventories contains a signal strength inventory to the target station, to select a single relay station to provide a call path from the originating station to the target station from the inventory information received, which call path requires a minimum overall expenditure of transmitter power between the originating station and the target station for the receipt

of the message at the target station at a signal to noise level above a preselected minimum, establish said call path between the originating station and the target station through said selected single relay station, and transmit said message over said call path at said minimum overall transmitter power expenditure;

(i) causing the originating station, if it cannot communicate either directly with the target station or with the target station through a single relay station, to transmit a second inventory request to each of said other stations which is a relay station, requesting each of said other relay stations to interrogate each relay station with which said other relay station can communicate to determine if the relay station being interrogated can communicate with the target station and, if so, transmit their identification codes and their signal strength and call path inventories, if any, with respect to the target station to said interrogating relay station;

(j) causing each of said other relay stations receiving the said second inventory request to transmit its identification code and its signal strength and call path inventories, if any, as to the target station to the interrogating station and causing said interrogating station to transmit said information, together with its own identification code and signal strength inventory with respect to the originating station to the originating station; and

(k) causing the originating station, if at least one of said other relay station inventories contains a call path inventory to the target station, to select a multiple relay station call path to the target station from the inventory information received, which call path requires a minimum overall expenditure of transmitter power for the receipt of the message at the target station at a signal to noise level above a preselected minimum, establish said selected multiple relay station call path between the

originating station and the target station, and transmit the message over said selected multiple relay station call path at said minimum overall transmitter power expenditure.

3. The method of either Claim 1 or Claim 2, and including the step, after the call path has been established between the originating station and the target station, of maintaining the continuity of the call path for a selectable time duration to permit two-way transmission of messages between the originating station and the target station, and initiating the two-way transmission of messages between said originating station and said target station over said call path so maintained.

4. The method of Claim 3, and including the step, prior to establishing the call path, of enabling at least one of said relay stations to be selectively removed from said network for relay purposes, whereby each of said selectively removed stations does not respond to any inventory request from other stations for the period of said selective removal.

5. The method of Claim 4, and in which each of said stations in said network is a wireless transceiver, and in which each of the transmissions between stations in the network is an electromagnetic radiation transmitted in space.

6. In a communications relay network, the combination of:

a plurality of relay stations;

means enabling each of said relay stations to communicate directly with at least two other stations in said network by acting as a relay station so as to relay a communication from one of said other stations to another of said stations through said relay station; and

means individually selectively operable at preselected ones of said relay stations to disable said relay station from operating as a relay station in said network for a selectable period of time.

7. The network of Claim 6, and in which each of said stations is so individually selectively operable.

8. In a communications network having a plurality of stations, and in which an originating station and a target station which cannot communicate directly with one another at a selected transmission power level, the steps of:

(1) causing at least one of the relay stations which can communicate directly with the originating station to transmit to the originating station information as to those other stations in the network with which the relay station can communicate and which can communicate with the target station;

(2) causing the originating station to select an arbitrary network of said relay stations to provide a serial call path to enable the message to be transmitted to the target station at a minimum expenditure of transmission power; and

(3) transmitting the message over the arbitrary network.

9. A relay communications network which is arbitrarily configured from a plurality of transceiver stations in a given geographic area to transmit a message at a minimum expenditure of transmission power by causing one of said stations which is to originate the transmission to interrogate those other of said stations with which it can communicate directly as to their ability to communicate either directly or indirectly with a target station, causing each of said other station which can communicate with the

target station to transmit to the originating station information as to a call path by which such relay station can communicate with the target station with a minimum expenditure of transmission power, and causing the originating station to select a serial call path through one or more of said relay stations, which serial call path permits the originating station to communicate with the target station with a minimum expenditure of transmission power.

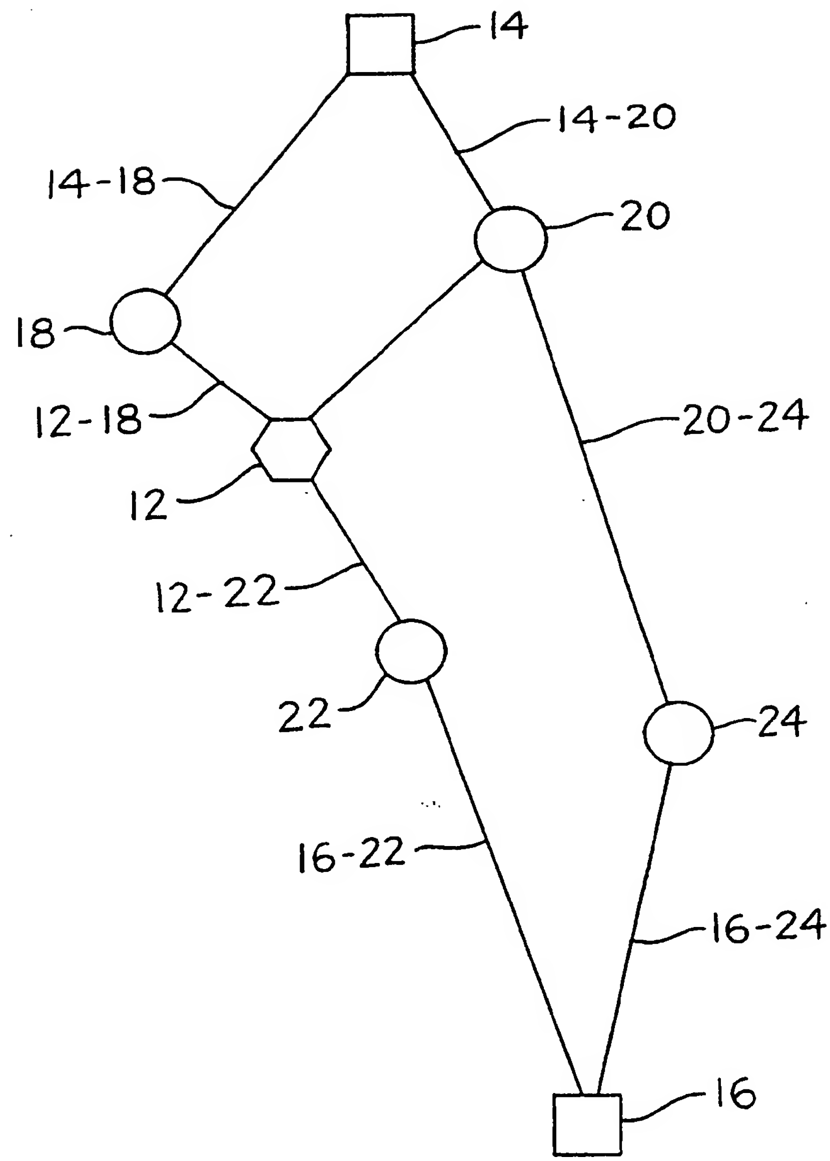
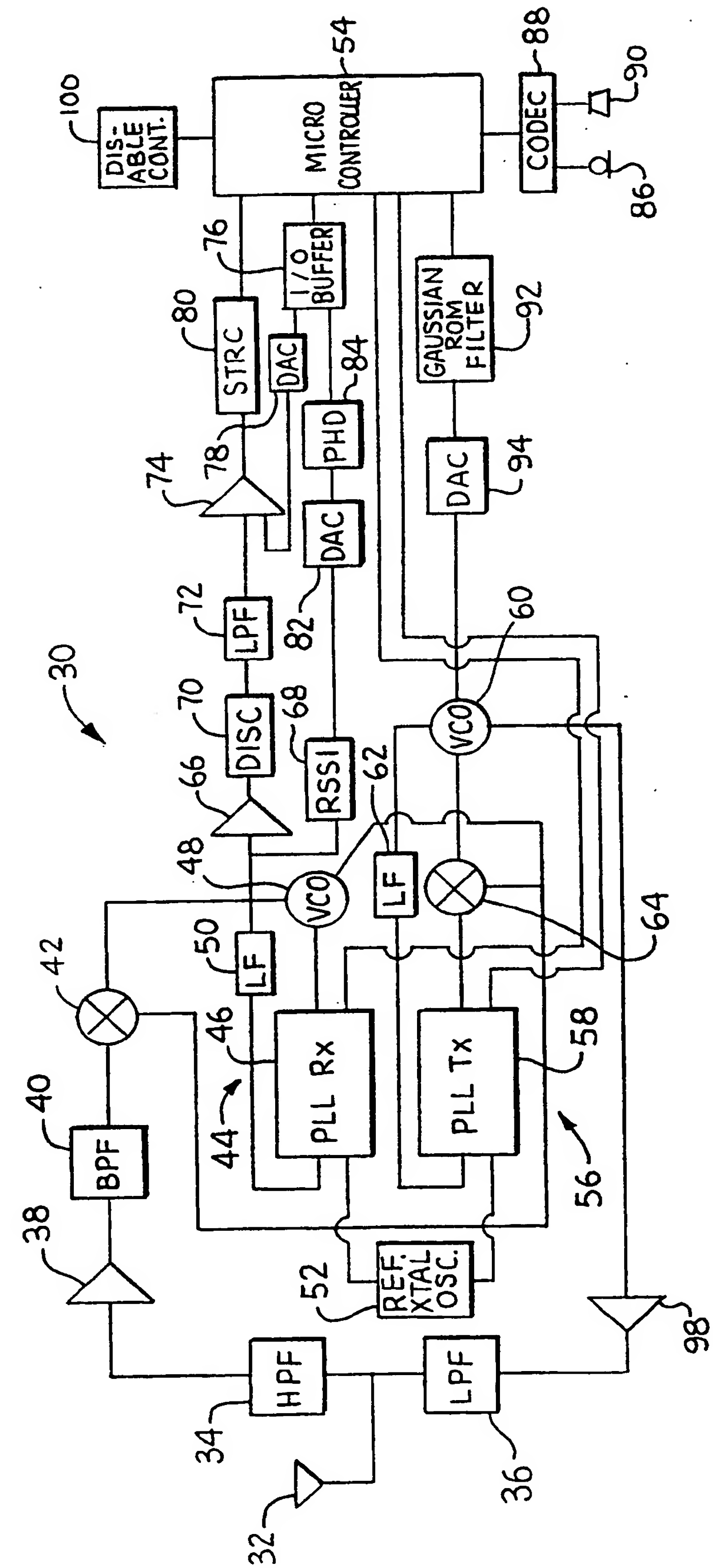


FIG. 1



MICRO CONTROLLER
DIS-ABLE CONT.
CODEC
I/O BUFFER
STRC
DAC
PHD
DAC
GAUSSIAN ROM FILTER
DAC
LPF
DISC
RSSI
VCO
LF
VCO
LF
PLL Rx
PLL Tx
BPF
REF. XTAL OSC.
HPF
LPF
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FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/11792

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04M 11/00; H04Q 7/00, 9/00, H04B 1/00
US CL :379/59, 60, 63; 455/33.1, 33.2, 54.1, 56.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 379/59, 60, 63; 455/33.1, 33.2, 54.1, 56.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,054,110 (COMROE ET AL) 01 October 1991, abstract, claim 1.	1-9
Y	US, A, 5,023,900 (TAYLOE ET AL) 11 June 1991, abstract	1-9
Y	US, A, 4,866,710 (SCHAEFFER) 12 September 1989, claims 1-4.	1-9
Y	US, A, 4,926,421 (KAWANO ET AL) 15 May 1990, col. 5, line 1--col. 6, line 48.	1-9
A	US, A, 5,020,091 (KROLOPP ET AL) 28 May 1991.	1-9
A	US, A, 3,906,166 (COOPER ET AL) 16 September 1975.	1-9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 JANUARY 1995	10 MAR 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer ALLAN A. ESPOSO Telephone No. (703) 305-4700

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